Development and Implementation of a Relocatable Coastal and Nearshore Modeling System

James M. Kaihatu
Zachry Department of Civil Engineering, Texas A&M University
3136 TAMU
College Station, TX 77843-3136
Phone: 979-862-3511 Fax: 979-862-8162 Email: jkaihatu@civil.tamu.edu

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LONG-TERM GOALS

The present project is part of a coherent effort to enhance and verify the nearshore modeling suite Delft3D and aid its transition to the operational Navy forecasting centers. Our present focus is on verification of the model and on the development of a forecast system within which Delft3D serves as the primary computational engine. The resulting system can be used for semi-automated, highly simplified model operation "on-scene," with automated incorporation of boundary and input conditions and grid resolution based on model behavior and bathymetric complexity.

OBJECTIVES

The objectives of the project are:

1) Accomplish initial development of the forecast system.
2) Test and evaluate modeling system.
3) Determine and evaluate model sensitivity to variations in the bathymetry and other environmental input.
4) Validate the improved model system and identify further areas for improvement.

APPROACH

The approach to the system development entails two separate parts. The first part considers development of system programming which allow for automated seeking and access to forcing and environmental conditions for a particular model run. This development will be undertaken primarily with the adaptation of Perl scripts previously developed at the Naval Research Laboratory (NRL), which allow for automated access of necessary inputs, creation of required input files, and output of results. The second part of the approach concerns aspects of the bathymetric information and required gridding. The initial implementation of the forecast system will not be entirely automated, as some operator judgment is required concerning the grid resolution relative to the nearshore bathymetry. However, during the course of the project we will investigate, using sensitivity analysis, the optimal grid resolution required for the model as a function of bottom complexity (curvature, etc.). The results are to be incorporated into a "grid resolution tool" to help guide selection of optimum resolution and grid configuration.

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In addition to the grid resolution tool, we have also used our proximity to the Texas coast as motivation to investigate processes at a tidal inlet (San Luis Pass). Our goal was to determine the efficacy of setting up the model for such a geographically complex area given only the software manual and tutorials as guides. Our more recent work involves the verification of the model with tide stations and buoys in the area, and the effect of simplifying features of the inlet-bay system on model performance. Simplification of these features serves as a proxy for sampling incompleteness or errors, and potentially highlights what features need to be included for accurate results.

To date, key personnel besides the PI on this project have included two graduate students (Dinesh Manian and Lt. Michael Jarosz) and one summer research assistant (William Mack). Both Mr. Manian and Mr. Mack were supported by this project, while Lt. Jarosz (Civil Engineer Corps) was supported by the U.S. Navy.

WORK COMPLETED

Our work concerning the inlet in Texas involves study of San Luis Pass (shown in Figure 1). It is located on the west side of Galveston Island and is one of only two unstructured inlets in Texas (Gibeaut et al. 2003). This area was chosen due to the lack of structures maintaining channel orientation and position. Additionally, a recent field exercise was done for the area (Gibeaut et al. 2003) and there was the opportunity for collaboration for data/model comparison in the inlet. (The recent passage of Hurricane Ike over Galveston Island has made the choice of this site a potentially fortuitous one.)

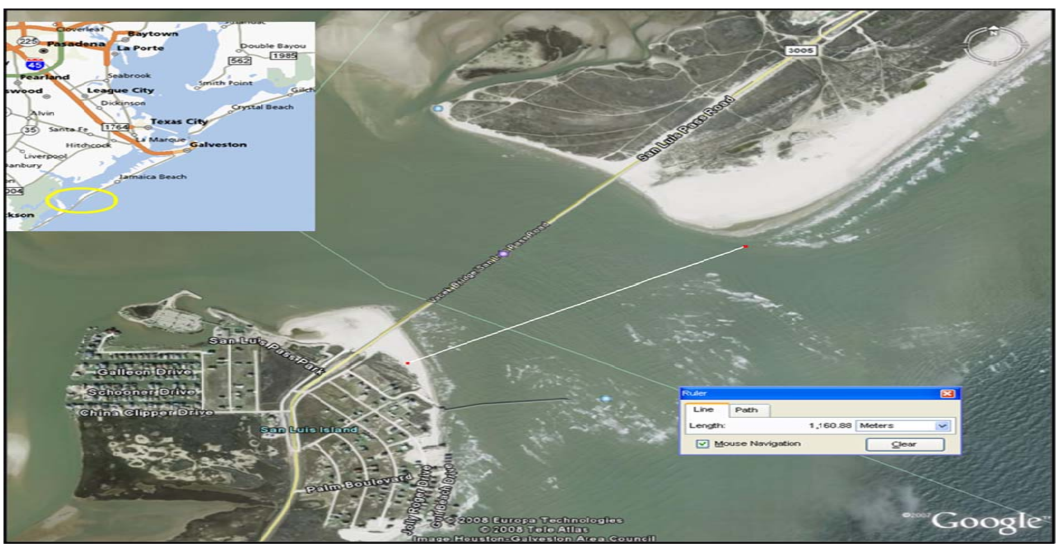

Figure 1. San Luis Pass, TX. Inset is Galveston, TX and vicinity.

San Luis Pass is characterized as a “mixed energy” tidal inlet, with features common to both wave-dominated and tide-dominated environments (Gibeaut et al. 2003). Compared to nearby Aransas Pass, San Luis Pass has a smaller tidal delta relative to its tidal prism, indicative of a smaller degree of sediment transport and storage. The opening of the inlet has been stable in position, but the channels within the opening have not. Adjacent shorelines have undergone drastic change due to the changes at the inlet.

Our focus with Delft3D is primarily with the wave, wind and tidal hydrodynamics. In FY07 we used Delft3D to simulate processes in the inlet, but concentrated on the issues of setting up the model, creating an optimal grid, and performing idealized test runs to determine the effect of wind waves vs. tidal currents in the area. The work resulted in a Master of Engineering project report (Mack 2008). In FY08 we moved toward simulation of waves and tidal hydrodynamics, with verification against tide stations and a buoy deployed by the National Data Buoy Center (NDBC). Agreement was found to be reasonable, especially considering that only archival bathymetry was used and no coefficient “tuning” was performed. We also investigated the effect of simplifying the domain and the simulation configuration on the results. These simplified scenarios included: allowing SWAN only two iterations instead of as many as required to come to convergence; smoothing the bathymetry inside (distant) Galveston Bay and the shoreline of Galveston Island; smoothing the small channels inside Sam Luis Pass; modeling the hydrodynamic environment without waves; and eliminating most of Galveston Bay. Sample comparisons to data are shown in Figure 2, and comparisons between the different configurations in Figure 3.

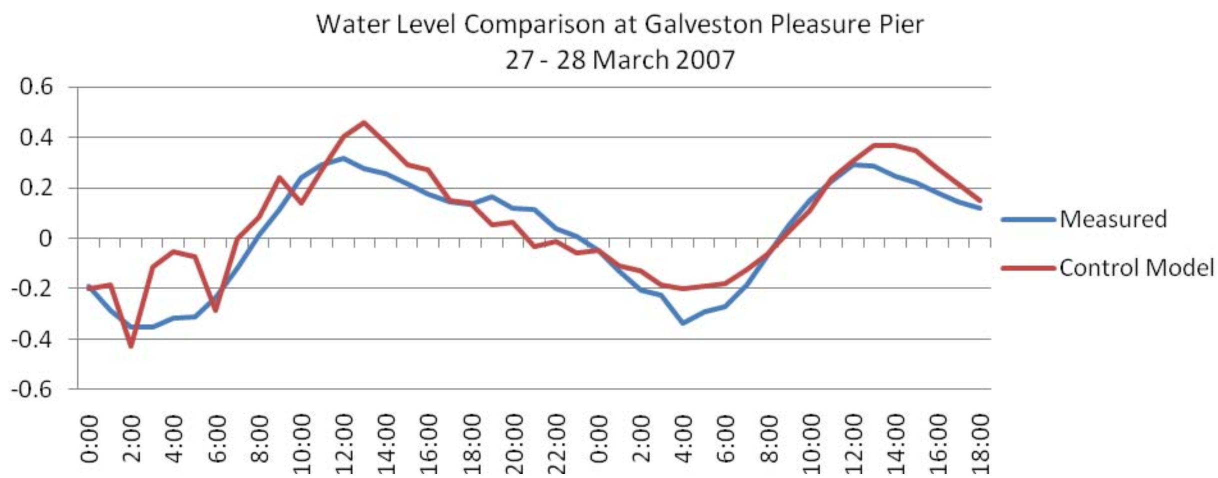

Figure 2. Water level comparison at Galveston Pleasure Pier.

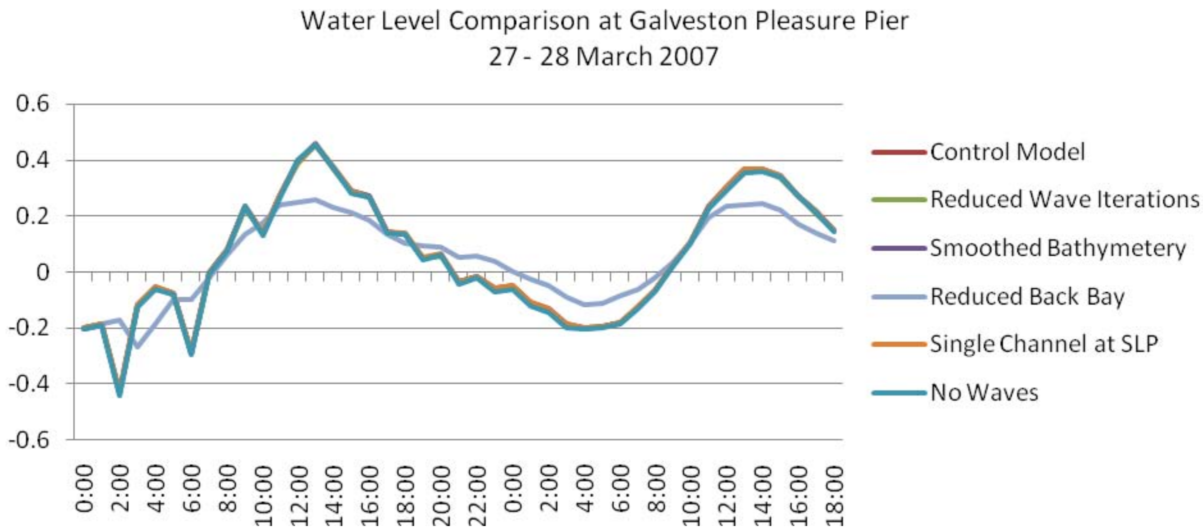

Figure 3. Comparison between control model and simplified runs: Water level comparison at Galveston Pleasure Pier.

With these comparisons we are able to determine which simplified scenario can still offer good fidelity to the physics compared to the control model.

We also evaluated the effect of under-resolution of the bathymetry on the predictions of the overlying waves and currents. This was done in a controlled manner, using idealized bathymetry which can be described in analytic forms (e.g., laboratory sandbar and shoal experiments).We concentrated on three laboratory experiments: random wave propagation over a shoal (Chawla et al. 1998); rip currents (Haas 2000); and longshore currents over a bar (Reniers and Battjes 1997). A snapshot of the simulation of rip currents (Haas 2000) is shown in Figure 4.

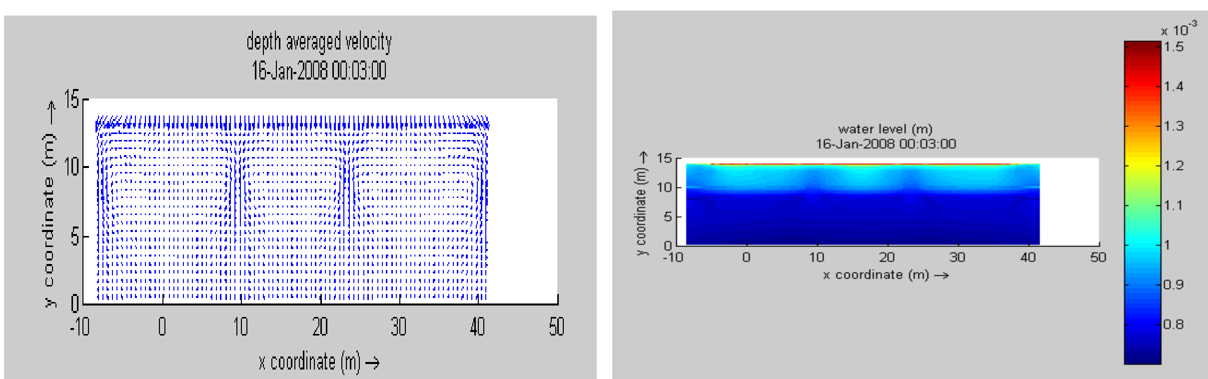

Figure 4. Delft3D current predictions; rip current case of Haas (2000). Left: Nearshore current field. Right: Water level predictions.

Model sensitivity to bathymetric input resolution was done two ways. First, we used successively coarser input bathymetric resolution and allowed the model to interpolate the bathymetry to its computational grid (to extract out the effects of resolution on the numerics, all runs were done with the same computational resolution). This would mimic errors on bathymetric sampling in the field. (We note that this was done independent of the scale of the bathymetric feature, in contrast to Plant et al. (2008)). Secondly, the sensitivity of modeled variables to variation of the analytic bathymetric parameters was also ascertained. This allows some degree of generalization of our results, and would also help determine which dimension of the feature would have the greatest effect on model results. Figure 5 shows two plots of change in error of root-mean-square waveheight and vorticity as the cross-shore spatial resolution of the input bathymetry is made coarser for the rip current experiment of Haas (2000). (*Note: the x-axis label should be "Grid spacing" rather than "Resolution"*).

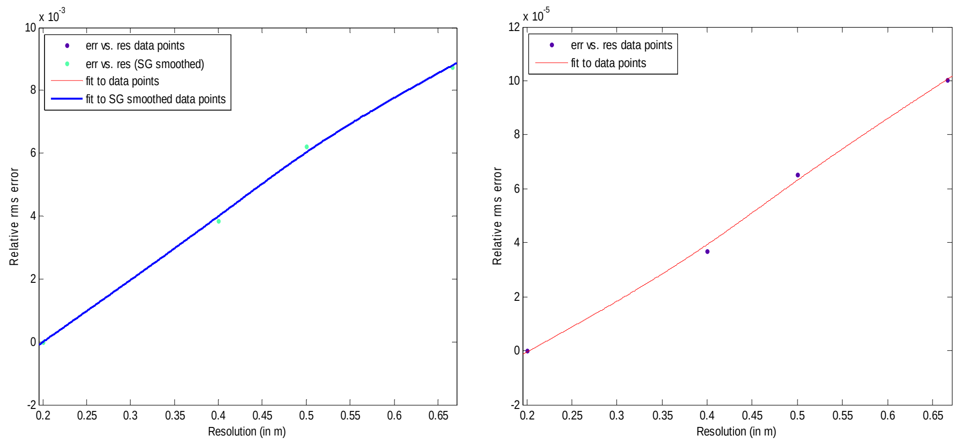

Figure 5. Dependence of prediction error on input bathymetric resolution, rip current experiment of Haas (2000) Left: Error in waveheight. Right: Error in vorticity.

Figure 6 shows the sensitivity of root-mean-square waveheight to sandbar length and distance of sandbar from the shoreline (both dimensions normalized by the rip channel width). (*Note: the x-axis label should be "Grid spacing" rather than "Resolution"*):

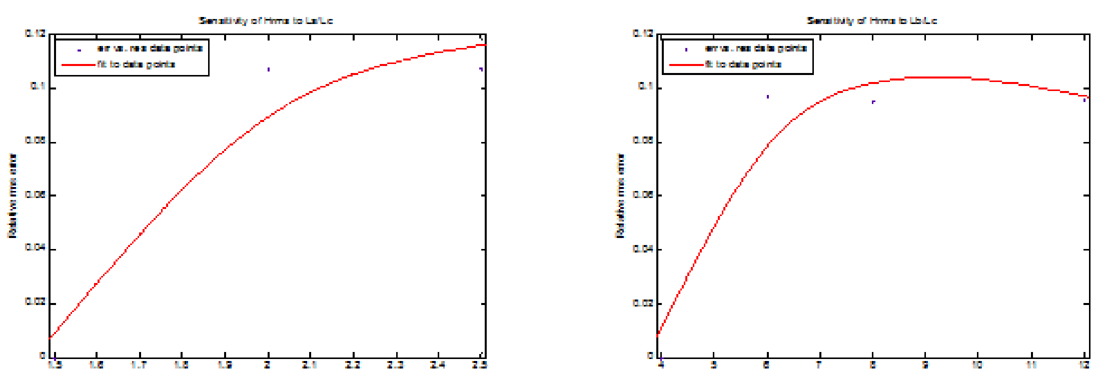

Figure 6. Sensitivity of H_{rms} to variation in parameters describing the bathymetric feature, rip current experiment of Haas (2000). Left: Sensitivity to distance of sandbar from shoreline. Right: Sensitivity to length of sandbar.

At present the model is being compared to available data sets. The effect of bathymetric resolution input on nearshore predictions will also be performed using the Nearshore Canyon Experiment (NCEX) bathymetry and data sets. We are also working on using the correlation between errors of modeled variables to errors in interpolated depth to provide a probable length scale to the sensitivity to bathymetric errors.

TRANSITIONS

None during FY07

RELATED PROJECTS

None

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